NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 3239

SOME ASPECTS OF THE HELICOPTER NOISE PROBLEM

By Harvey H. Hubbard and Leslie W. Lassiter

Langley Aeronautical Laboratory
Langley Field, Va.

Washington
August 1954

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 3239

SOME ASPECTS OF THE HELICOPTER NOISE PROBLEM

By Harvey H. Hubbard and Leslie W. Lassiter

SUMMARY

Some aspects of the helicopter noise problem are briefly discussed. These discussions deal with the nature of the problem, some tentative criteria for use in evaluating it, and the physical characteristics of noise from helicopters. Overall noise data are presented for a reciprocating-engine helicopter along with discussions of the characteristics of noise from its various components such as the engine, gearing, and rotors. Some consideration is also given to the noise from tip jet rotor systems.

INTRODUCTION

Until recently noise has not received so much attention as many of the other problems which face the operators of helicopters. Although the difficulties associated with communications in the presence of noise continue to exist, some new noise problems have arisen with the advent of the passenger-carrying helicopter. Some consideration must now be given to the comfort of the passengers as well as the neighbors in the vicinity of heliports and along routes of flight.

Very few studies are available in the literature which deal directly with the noise from helicopters; however, data on noise from propellers, engines, jets, and so forth are available from other noise studies and some of this information can be applied to helicopter noise problems. The purpose of this paper therefore is to indicate the nature of the problem and to present some information that is of general interest in connection with helicopter noise studies.

INTERNAL NOISE PROBLEM

Figure 1 which was taken from reference 1 shows the envelope of noise spectrums inside several helicopters and compares these with some average levels measured in current airliners. Shown also on this figure is an acoustical comfort index curve from the work of reference 2. Based on airline experience, noise spectrums higher than this curve are definitely uncomfortable for passengers and the optimum conditions of comfort exist only when the noise is well below the values shown here. Thus, from a comfort standpoint the noise levels in current helicopters tend to be rather high, although it must be recognized that, for flights of a few minutes duration, the passenger may be willing to tolerate a considerably higher noise level than for flights of several hours.

Although it is recognized that some benefits for the passenger may be realized from the use of additional sound treatments, discussions along these lines are beyond the scope of this paper. Emphasis is placed on phenomena related to noise reduction at the source since these are of interest to both the occupant of the aircraft and the ground observer. The phase of the helicopter noise problem which may be the most serious from the commercial operator's point of view involves the ground observer and it is this phase of the problem with which the remainder of the paper will be concerned.

EXTERNAL NOISE PROBLEM

Community Noise

The significance of some of the noise data which will be shown later can best be appreciated if the nature of other noises in the communities in which helicopters will operate is known. Some of these are shown in figure 2 (ref. 3). Noise levels are plotted as a function of frequency in octave bands for the noise in residential areas, industrial areas, and for highway traffic. Some variations exist in the levels of various frequency bands; however, it is seen that, in general, these spectrums have a characteristic shape. They peak in approximately the 75 to 150 cps band and fall off rather gradually as the frequency increases. One way of making a noise less objectionable is to place it in an environment which is already noisy and which has a similar noise spectrum. Thus, if the shape of the helicopter noise spectrum resembles these general shapes, it will not be so conspicuous as if, for instance, it had very intense high-frequency components.

Tolerance Criteria

Another reason why high-frequency noises are undesirable in a community environment is given in figure 3 which illustrates some tolerance criteria that have recently been made available in reference 4. Although criteria are given for sleep and rest, speech interference, and permanent hearing damage, not all of these are considered for the purposes of this paper. Only those pertaining to speech interference have been made use of and these are given in figure 3. Noise levels in decibels are plotted as a function of frequency for speech-interference levels (S.I.L.) of 45, 55, 65, and 75. The number values represent the average number of decibels in the 600 to 1200 cps, 1200 to 2400 cps, and 2400 to 4800 cps bands as indicated by the vertical dashed lines and which are considered the most important for speech communication. These curves are based on one's ability to understand conversational speech in the presence of noise and it should be noted that high-frequency noises are more detrimental to speech communication than low-frequency noises. As an example, if the noise spectrum fits in below the curve for S.I.L. = 45, normal speech should be possible in the presence of that noise.

By definition, any noise which exceeds the requirements of the curve S.I.L. = 45 will interfere in some way with normal conversational speech. The following requirements for communication in the presence of noise levels corresponding to various speech-interference-level curves are given briefly, from reference 4, as follows: (a) S.I.L. = 45, normal voice at 10 feet; (b) S.I.L. = 55, normal voice at 3 feet, raised voice at 6 feet; (c) S.I.L. = 65, raised voice at 2 feet, very loud voice at 4 feet; and (d) S.I.L. = 75, very loud voice at 1 foot (minimal efficiency). As a matter of interest it can be noted that the highest levels of community noise of figure 2 approximately correspond to those of the curve for S.I.L. = 55 which is used as a basis for some of the calculations of this paper.

Effect of Distance

One way in which any noise problem may be alleviated is to separate the observer by a sufficient distance from the source of the noise. An understanding of the way in which noise is attenuated as a function of distance is thus desirable and this phenomenon is illustrated in figure 4.

A noise spectrum measured for a reciprocating-engine-type helicopter overhead at 100 feet is shown by the solid curve at the top of the figure. These values are adjusted for distance to give the dotted-line spectrums at distances of 300 feet, 1,000 feet, and 3,000 feet. Adjustments for distance are made in accordance with the data of references 5 and 6 and for the assumption of no terrain and wind effects. It can be seen that the high frequencies are attenuated more with distance than the low frequencies are and, as a result of this phenomenon, the spectrum changes shape as it propagates through space.

The curve for S.I.L. = 55 from figure 3 is replotted here and it can be seen that at a distance of 3,000 feet, the noise spectrum of this helicopter meets the requirements of this criterion. Measurements of the type shown here, that is octave-band measurements, are useful in evaluating the seriousness of a problem but give very little information as to the source of the noise. Consequently, the first few bands of the noise have been analyzed by means of a 20-cycle-wide filter arrangement and the results are shown in figure 5.

Sources of Helicopter Noise

Sound pressures in linear units are shown as a function of frequency also on a linear scale. Relative pressure amplitudes are given for the frequency range of approximately 100 cps to 1400 cps. Since the measuring system for these tests did not record below 100 cps, the estimated levels in that frequency range are indicated by the dashed line. Detailed noise studies for this particular helicopter have made it possible for the bulk of the noise in certain frequency bands of figure 5 to be associated with parts of the helicopter such as engine exhaust, gearing, and so forth, as labeled in figure 5. For instance, noise from the tail rotor appears mainly in the frequency range below 150 cps and has a relatively low level. For the range of approximately 150 cps to 600 cps, within which some of the highest noise levels were recorded, the bulk of the noise is associated with the engine. Noise from the gear box is included in the range of frequencies between 600 cps and 1200 cps, and it is also seen to be a major source of noise. In general, the noise from about 1200 cps to 15,000 cps appeared to be completely random in nature and it is believed that much of this random noise is due to the shedding of vorticity from the main rotor. Random noise from the rotor will also appear in the spectrum below 1200 cps but for the operating conditions of this test the discrete frequencies from the engine exhaust and the gearing are much more pronounced.

<u>Reciprocating engine</u>.- The main source of the noise from the reciprocating engine is the exhaust. The sound pressure levels vary as a function of the type of manifold used and, for a given type of engine, it has been estimated in reference 7 that a 3-decibel increase results from a doubling of the engine power. The noise from the exhaust (fig. 5) is related to a nine-cylinder engine which has only one exhaust exit. The fundamental firing frequency of this engine is approximately 150 cps. The noise consists mainly of discrete frequencies in the range below 600 cps. The present tests as well as the more detailed studies of reference 8 show that the spectrum levels drop off rapidly with increasing frequency above approximately 600 cps. Although it is recognized that there is some noise associated with the high-velocity exhaust-gas streams, this component of noise is thus seen to be much lower in level than the discrete low-frequency components. The other engine noises from valves, gears, carburetor, supercharger, and so forth are believed to be in approximately the same frequency range and are usually 10 to 15 decibels below the level of those from the exhaust (ref. 9).

For any given reciprocating engine, the exhaust muffler can be used as a means of reducing the exhaust noise. Mufflers are usually designed for a particular type of engine since such variables as engine firing frequency, volume of gas flow, and the desired attenuation characteristics are important factors in the design. Although further discussions with regard to exhaust muffling are beyond the scope of this paper, considerable information relating to mufflers and muffling techniques for aircraft engines is included in references 10 and 11.

Gearing.- Gear noise arises from the meshing of gear teeth and may consist of two components as indicated schematically in figure 6. As might be expected, one noise component corresponds to the tooth-contact frequency which is a function of the number of gear teeth and the rotational speed of the gear. Some results of reference 12, relating to the noise from automobile transmissions, indicate that another component of noise may arise from the excitation of natural frequencies of the system. When these natural frequencies of the tooth-gear combinations were at or near some integral multiple of the tooth-contact frequency, a very strong noise component was detected. For the tests of reference 12, these natural frequencies were very important with regard to noise; however, for the measurements of figure 5, it appears that some of the tooth-contact frequencies were clearly predominant.

Rotor systems including tip jets.- The noise from rotors can also be conveniently considered as two separate components, namely, the rotational and vortex components. These are shown qualitatively in figure 7 which gives a noise spectrum for conditions where these two components are of the same order of magnitude. Figure 7, which was taken from reference 13, relates directly to an airplane propeller but these results are believed to apply qualitatively to helicopter rotors as well. The rotational component consists of several discrete tones that are associated with the steady aerodynamic forces on the blades and are most intense in or near the plane of rotation. The vortex component has a continuous-type spectrum that is associated with the unsteady aerodynamic forces on the blades. This component is most intense on the axis of rotation. For the blade geometries and operating conditions currently used, the noise from the tail rotor is mostly rotational noise, whereas vortex noise is the main component from the main rotor.

As in the case of propellers (ref. 13), the rotational noise increases for increased power loading and tip speed and decreases with an increased number of blades. The vortex noise increases with the tip speed of the blades and the blade area and is essentially independent of the power loading and number of blades. This noise can best be kept at a low level by keeping the tip speed low.

In addition to the basic noise from helicopter main rotors, the use of tip jets will superimpose additional sources of noise. The associated noise spectrums will depend on the type of tip jet propulsion used as indicated schematically in figure 8. If pulse jets are used, the noise is mainly associated with the firing frequency of the engine (refs. 14 to 16). The spectrum thus contains a few intense low-frequency discrete components as well as some low-level random components associated with the discharge of the exhaust gases. The fact that much of the noise energy from this type of jet appears in a few discrete frequencies suggests that some noise reduction is obtainable if it were feasible to operate multiple units in proper phase.

The noise from pressure jets consists mainly of random components as indicated schematically in figure 8. During operation at low temperatures, an additional discrete component may appear in the spectrum as indicated by the dashed vertical line. This component is associated with a resonance phenomenon involving the shock-wave formations in the jet stream and, for certain overpressured operating conditions, can be very intense (refs. 17 and 18). Tests have shown, however, that, at high jet temperatures, this noise component is much less pronounced than at low jet temperatures and thus may not be of much concern. There is some indication that the noise from pressure jets is a function of the relative velocity between the jet and the surrounding medium and that the noise from jets in motion is less than in the static case.

In order to compare the noise from various main rotor systems for a 7,000-pound-gross-weight helicopter, the bar chart of figure 9 has been prepared. The abscissa scale is the vertical distance which the particular noise source in question would have to be from an observer in order that its noise would satisfy the speech-interference-level criterion curve labeled 55 which was defined in a discussion of figure 3. Spectrums for these various sources were adjusted for atmospheric losses as in figure 4. In addition to the rotor systems considered, data are included for the helicopter of figure 4 and for a four-engine transport airplane from reference 19 for comparison. When the bar chart is interpreted, it should be noted that the lesser distances are associated with the more desirable noise conditions.

The estimated data for the main rotor of the helicopter for which measurements were made are shown in the second bar from the top. The crosshatched part indicates the estimated increased distance required for an increase in the rotor tip speed from approximately 550 feet per second to 800 feet per second. Thus in the event that rotor tip speeds are increased substantially, the rotor noise levels may then be comparable to the overall noise from current helicopters. The data shown here for the basic rotor are to be interpreted as minimum values because it is believed that, for some operating conditions, the rotor may contribute more substantially to the overall noise than is indicated by figure 9.

When tip jets are used, that is one jet on each blade tip, the rotor system will probably be one of the primary noise sources. For instance, as indicated in the bar chart, the noise from both conventional pulse-jet and pressure-jet rotor systems will probably be much greater than for the bare rotor and will be greater than the overall noise from current helicopters. It should be noted that, for the conditions of figure 9, the observer is assumed to be oriented on the axis of rotation of the rotor. If the observer were in the plane of the rotor, the noise for the bare rotor would be less objectionable and for both tip jet rotors would be more objectionable than indicated in the figure.

CONCLUDING REMARKS

Some of the sources of the noise from helicopters as well as some general information relating to the ground noise problem of helicopters have been discussed. It has been shown that, for helicopters of current design, the engine and accessories such as the gearing are primary sources of noise. For comparable-sized helicopters utilizing tip jet propulsion, the noise levels will be considerably higher and the rotor system may then be one of the primary sources of noise.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., June 11, 1954.

REFERENCES

1. Douglas, L. L.: The Short-Haul Helicopter - An Engineer's View. American Helicopter Society. (Presented at meeting of American Helicopter Society, Washington, D. C., Nov. 4, 1953.)

2. Lippert, Stanley, and Miller, Matha M.: A Method for Evaluating Aircraft Acoustical Comfort. Reprinted from Jour. Aviation Medicine, vol. 23, Feb. 1952, pp. 54-66.

3. Anon.: Chicago Noise Survey. The Frontier, vol. 14, no. 4 (Armour Res. Foundation, Ill. Inst. Tech.), Dec. 1951, pp. 9, 15-19.

4. Parrack, Horace O.: Physiological and Psychological Effects of Noise. Proc. Second Annual National Noise Abatement Symposium, vol. 2, Technology Center (Chicago), Oct. 5, 1951, pp. 21-38.

5. Regier, Arthur A.: Effect of Distance on Airplane Noise. NACA TN 1353, 1947.

6. Ingard, Uno: The Physics of Outdoor Sound. Proc. Fourth Annual National Noise Abatement Symposium, vol. 4, Oct. 23-24, 1953, pp. 11-25.

7. Rudmose, H. Wayne, and Beranek, Leo L.: Noise Reduction in Aircraft. Jour. Aero. Sci., vol. 14, no. 2, Feb. 1947, pp. 79-96.

8. Stokes, George M., and Davis, Don D., Jr.: The Attenuation Characteristics of Four Specially Designed Mufflers Tested on a Practical Engine Setup. NACA TN 2943, 1953.

9. McFarland, Ross A.: Human Factors in Air Transport Design. McGraw-Hill Book Co., Inc., 1946.

10. Davis, Don D., Jr., Stevens, George L., Jr., Moore, Dewey, and Stokes, George M.: Theoretical and Measured Attenuation of Mufflers at Room Temperature Without Flow, With Comments on Engine-Exhaust Muffler Design. NACA TN 2893, 1953.

11. Davis, Don D., Jr., and Czarnecki, K. R.: Dynamometer-Stand Investigation of a Group of Mufflers. NACA TN 1838, 1949.

12. Glaubitz, H., and Goesele, K.: Experiments on the Origin of Gear Noise. R.T.P. Translation No. 2293, British Ministry of Aircraft Production. (From A.T.Z., no. 7, Apr. 10, 1942, pp. 175-181.)

13. Hubbard, Harvey H.: Propeller-Noise Charts for Transport Airplanes. NACA TN 2968, 1953.

14. Lassiter, Leslie W.: Noise From Intermittent Jet Engines and Steady-Flow Jet Engines With Rough Burning. NACA TN 2756, 1952.

15. Powell, Alan: The Noise of a Pulse Jet. Jour. Helicopter Assoc. of Great Britain, vol. 7, no. 1, July 1953, pp. 32-41.

16. Veneklasen, Paul S.: Noise Characteristics of Pulse-Jet Engines. Symposium on Aircraft Noise. (Reprinted from Jour. Acous. Soc. of America, vol. 25, no. 3, May 1953, pp. 378-380.)

17. Lassiter, Leslie W., and Hubbard, Harvey H.: The Near Noise Field of Static Jets and Some Model Studies of Devices for Noise Reduction. NACA TN 3187, 1954.

18. Powell, Alan: A Survey of Experiments on Jet Noise. Aircraft Engineering, vol. XXVI, no. 299, Jan. 1954, pp. 2-9.

19. Hubbard, Harvey H.: Airplane and Airport Noise. Proc. Fourth Annual National Noise Abatement Symposium, vol. 4, Oct. 23-24, 1953, pp. 81-88.

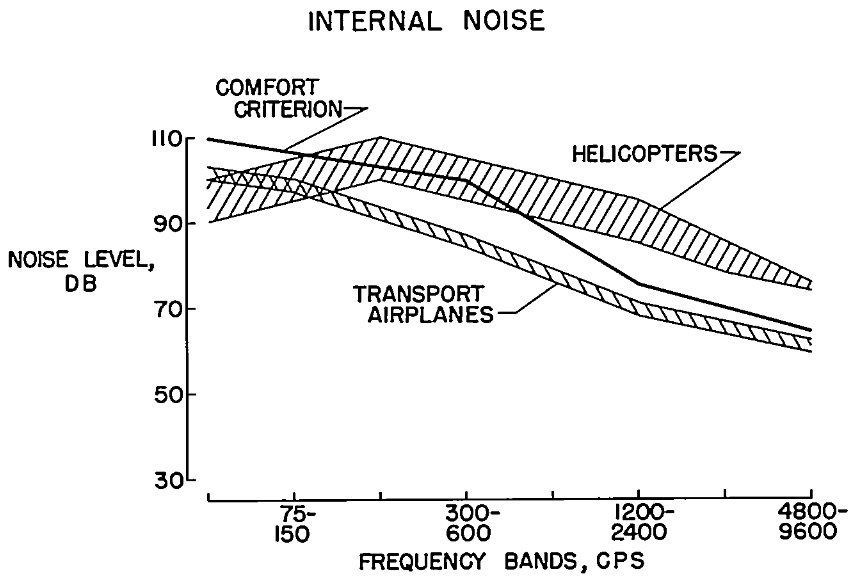

Figure 1

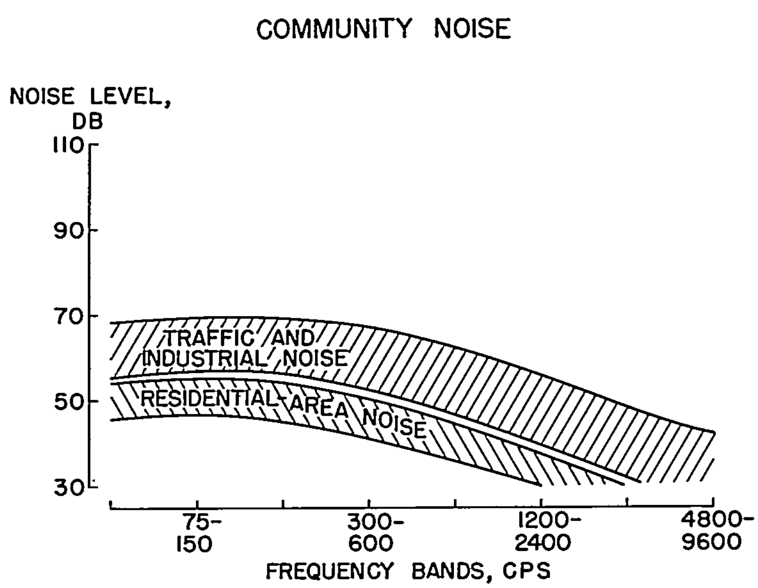

Figure 2

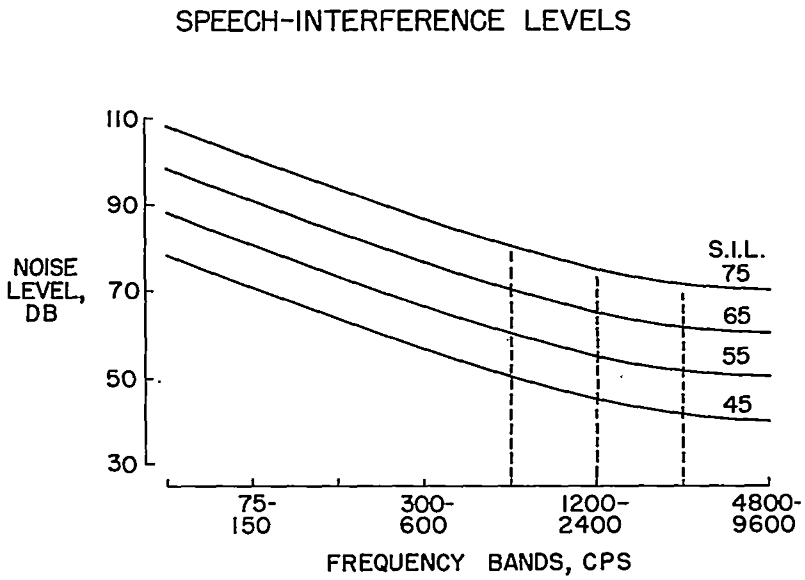

Figure 3

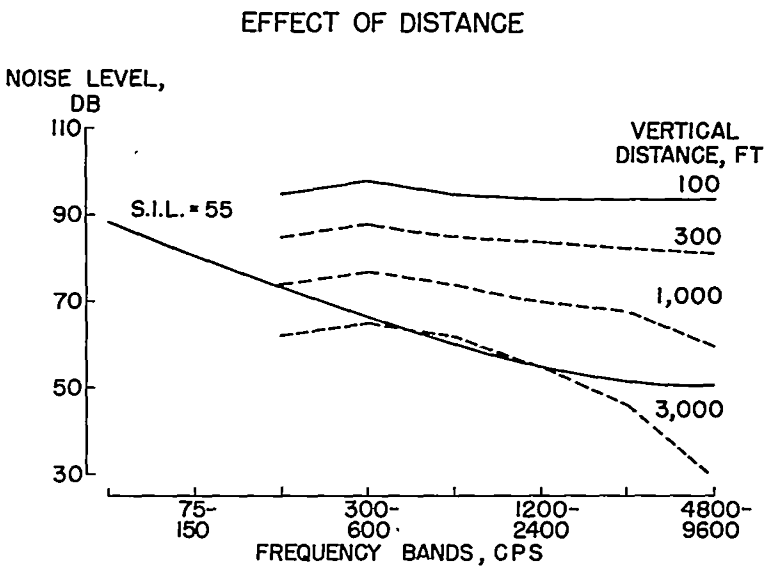

Figure 4

NOISE FROM HELICOPTER IN HOVERING

FREQUENCY ANALYSIS WITH 20-CYCLE-WIDE FILTER

SOUND PRESSURE, DYNES/CM²

8

ENGINE EXHAUST

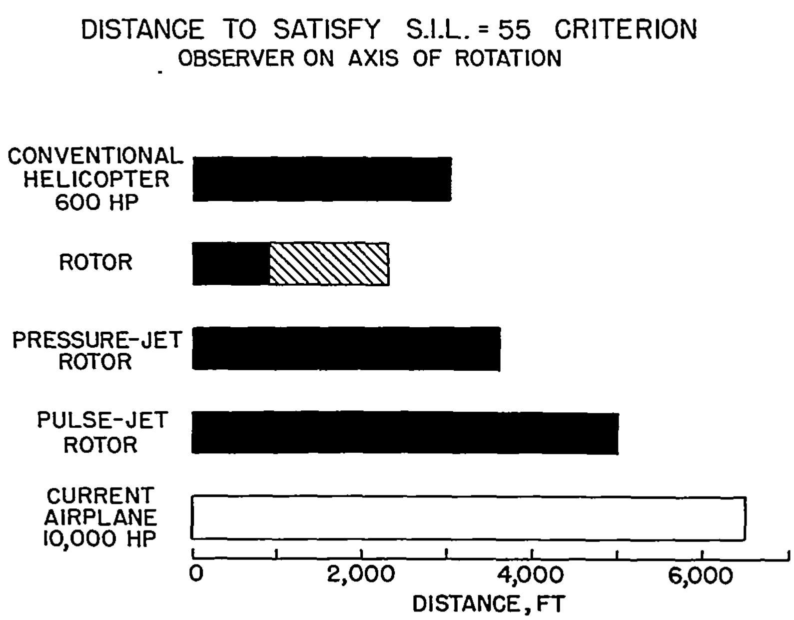

Figure 9

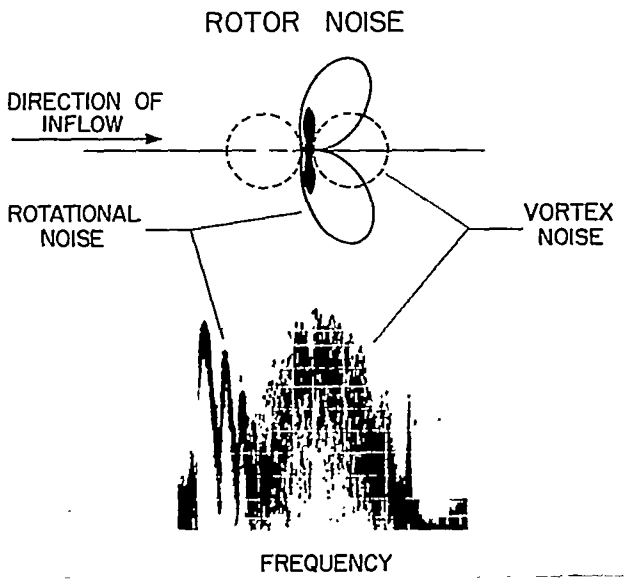

Figure 7

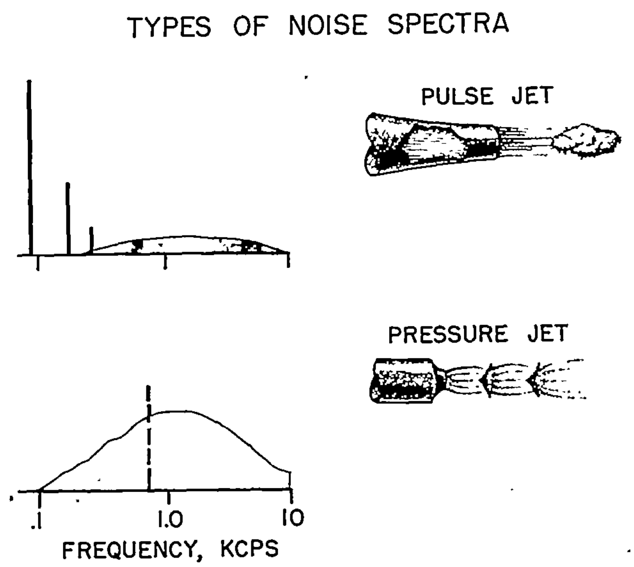

Figure 8

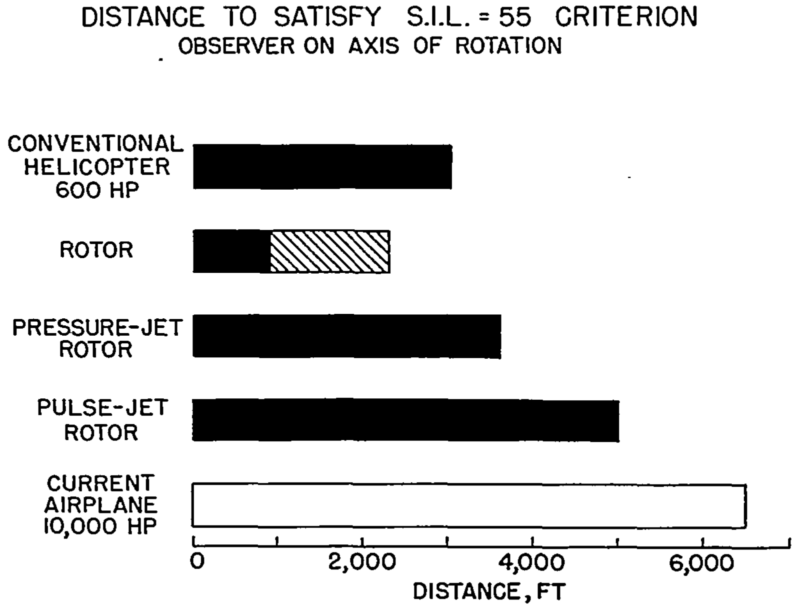

Figure 9

NACA-Langley - 8-20-54 - 1000